

ORTHORECTIFICATION OF SPOT-4 DATA USING RATIONAL POLYNOMIAL COEFFICIENTS

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Abstract. Orthorectification of satellite imagery can be done in two ways i.e., rigorous sensor model and the approximation model of the satellite's orbit. Dependence on physical parameters, to make rigorous sensor model is more complicated and difficult to apply. The approximation model can be either Rational Polynomial Coefficients (RPC) model or parallel projection system. RPC is a mathematical model which is not depends on the sensor. It is used to improve the positioning accuracy when the parameter of the physical sensor model is unknown. This study assessed orthorectification of SPOT-4 using the RPC model with 7 coefficients. Root Mean Square Error (RMSE) of GCPs obtained from the study was less than 1 pixel. RPC did not depend on physical and satellite orbit parameters. Thus the RPC was simpler and easier to apply.

Keywords: *Orthorectification, Rational polynomial coefficient, SPOT-4*

1 INTRODUCTION

Orthorectification is a process of transformation to a map coordinate system using the Digital Terrain Models (DTM) data to correct the relief displacement (Baltsavias, 2000). Basically, orthorectification is an image manipulation process to reduce/eliminate the distortions which are caused by tilt of camera sensor and relief displacement. On aerial photographs, relief displacement is removed by differential rectification (Frianzah, 2009). A schematic of a relief displacement correction using DTM data is presented in Figure 1.

Orthorectification of satellite imagery can be done in two ways, i.e. rigorous sensor model and the approximation model of the satellite's orbit. Dependence on physical and satellite's orbit parameters to make rigorous sensor model is more complicated and difficult to apply. Rigorous Sensor Model (RSM) is generally only available at the satellite owners and not given to the public. The approximation model can be either Rational Polynomial Coefficients (RPC) model or parallel projection system (Harintaka *et al.*, 2007).

RPC model is highly prospective for orthorectification of satellite image used with consideration that does not require information of interior orientation parameters (IO) and exterior (EO). RPC

method is also used to improve the positioning accuracy when the parameters of the physical sensor model is unknown (Zhan *et al.*, 2008). RPC is a mathematical model which is not depend on the sensor and has been used extensively by the satellite companies for the High Resolution Satellite Imagery (HRSI) and as an alternative of orthorectification method to the RSM.

Several studies of satellite imagery orthorectification have been widely applied, such as Ganas *et al.* (2001), Tonolo and Poli (2003), Tong *et al.* (2010) and Zhan *et al.* (2008). Ganas *et al.* (2001) studied orthorectification of IKONOS Geo imagery using 17 Ground Control Points (GCP) and the Digital Terrain Models (DTM) data. RMSE in this studied was 0.6 pixels and RMSE at the check points was less one pixel. Based on these results, the level of IKONOS Geo imagery can be processed to produce images with higher accuracy. Tonolo and Poli (2003) studied orthorectification of EROS imagery using 40 GCP and the DTM data. RMSE in this study was 0.7 meters and 5.04 meters at the check points. The objective of this study was to perform RPC using SPOT-4 data and Digital Elevation Model (DEM) data using seven coefficients and 15 points of GCP.

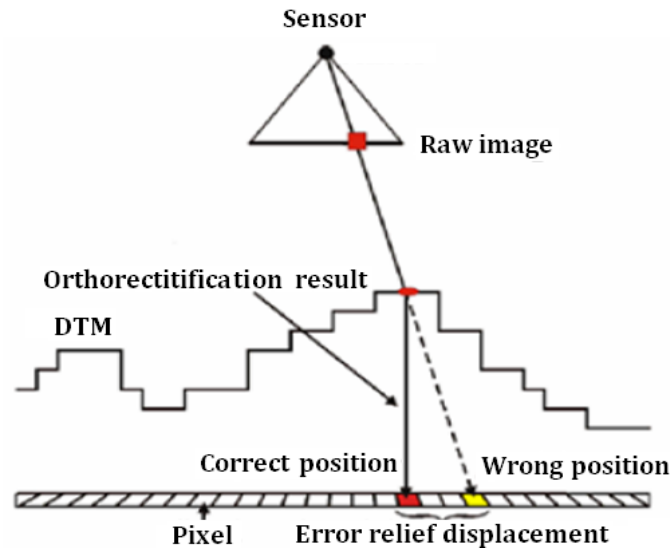


Figure 1. The relief displacement correction using DTM data (PCI, 2005)

2 MATERIALS AND METHOD

2.1 Data

Satellite SPOT-4 with path/row (286/364) acquired on November 12th, 2010 was used in this study. The data had varying heights and cloud coverage less than 20%. The Landsat Ortho USGS data was used as reference data. The Shuttle Radar Topography Mission (SRTM) data was used for the DTM.

The SPOT-4 satellite has two identical optical instruments i.e., HRVIR (Visible & Infrared High-Resolution) sensors. The HRVIR sensors are very similar to the HRV sensors of the previous generation (same spatial resolution and possibility of orienting the mirrors). The sensor has the ability to oblique viewing with an angle approximately 27° relative to the vertical direction.

SPOT-4 data has different geometric accuracy levels, such as 1A (uncorrected), 1B (systematic geometric corrected), 2A (corrected to a standard map projection), 2B (geometric corrected using GPS) and 3 (geometric corrected using GCP and DEM/Ortho). The levels 1A, 1B, and 2A have a geometric accuracy up to 350 m whereas level 2B depends on the quality of GPS measurements. The best accuracy is at level 3. At this level, the accuracy is up to 10 m. In this study, the SPOT-4 data was level 2A.

2.2 Method

The RPC model was transformed 3-dimensional of the object-image coordinates into 2-dimension (Grodecki and Dial, 2001). The RPC model is a ratio of two cubic polynomials of the object coordinates, and provides a functional between object coordinates and image coordinates (Frianzah, 2009). Rational function of row

and column by (Grodecki and Dial, 2003) is as follows:

$$Y = \frac{N_L(U, V, W)}{D_L(U, V, W)} = \frac{c^T u}{d^T u}$$

$$X = \frac{N_S(U, V, W)}{D_S(U, V, W)} = \frac{e^T u}{f^T u}$$
(1)

where

$$N_L(U, V, W) = c_1 + c_2V + c_3U + c_4W + c_5VU + c_6VW + c_7UW + c_8V^2 + c_9U^2 + c_{10}W^2 + c_{11}UVW + c_{12}V^3 + c_{13}VU^2 + c_{14}VW^2 + c_{15}V^2U + c_{16}U^3 + c_{17}UW^2 + c_{18}V^2W + c_{19}U^2W + c_{20}W^3 = c^T u$$

$$D_L(U, V, W) = 1 + d_2V + d_3U + d_4W + d_5VU + d_6VW + d_7UW + d_8V^2 + d_9U^2 + d_{10}W^2 + d_{11}UVW + d_{12}V^3 + d_{13}VU^2 + d_{14}VW^2 + d_{15}V^2U + d_{16}U^3 + d_{17}UW^2 + d_{18}V^2W + d_{19}U^2W + d_{20}W^3 = d^T u$$

$$N_S(U, V, W) = e_1 + e_2V + e_3U + e_4W + e_5VU + e_6VW + e_7UW + e_8V^2 + e_9U^2 + e_{10}W^2 + e_{11}UVW + e_{12}V^3 + e_{13}VU^2 + e_{14}VW^2 + e_{15}V^2U + e_{16}U^3 + e_{17}UW^2 + e_{18}V^2W + e_{19}U^2W + e_{20}W^3 = e^T u$$

$$D_S(U, V, W) = 1 + f_2V + f_3U + f_4W + f_5VU + f_6VW + f_7UW + f_8V^2 + f_9U^2 + f_{10}W^2 + f_{11}UVW + f_{12}V^3 + f_{13}VU^2 + f_{14}VW^2 + f_{15}V^2U + f_{16}U^3 + f_{17}UW^2 + f_{18}V^2W + f_{19}U^2W + f_{20}W^3 = f^T u$$

To determine the RPC coefficients (ci, di, ei, fi) number of GCPs were required with a minimum number is 7 (order 1) to 39 (order 3) (Harintaka *et al.*, 2007). The order means the maximum number of power in the equation. To improve numerical accuracy, object and image coordinates were inserted to be normalized to the range -1 ≤ x ≤ 1 (Grodecki, *et al.*, 2004).

Candra (2001) studied that the normalization and denormalization techniques built in the study have the same ability compared to the normalization and denormalization techniques built by

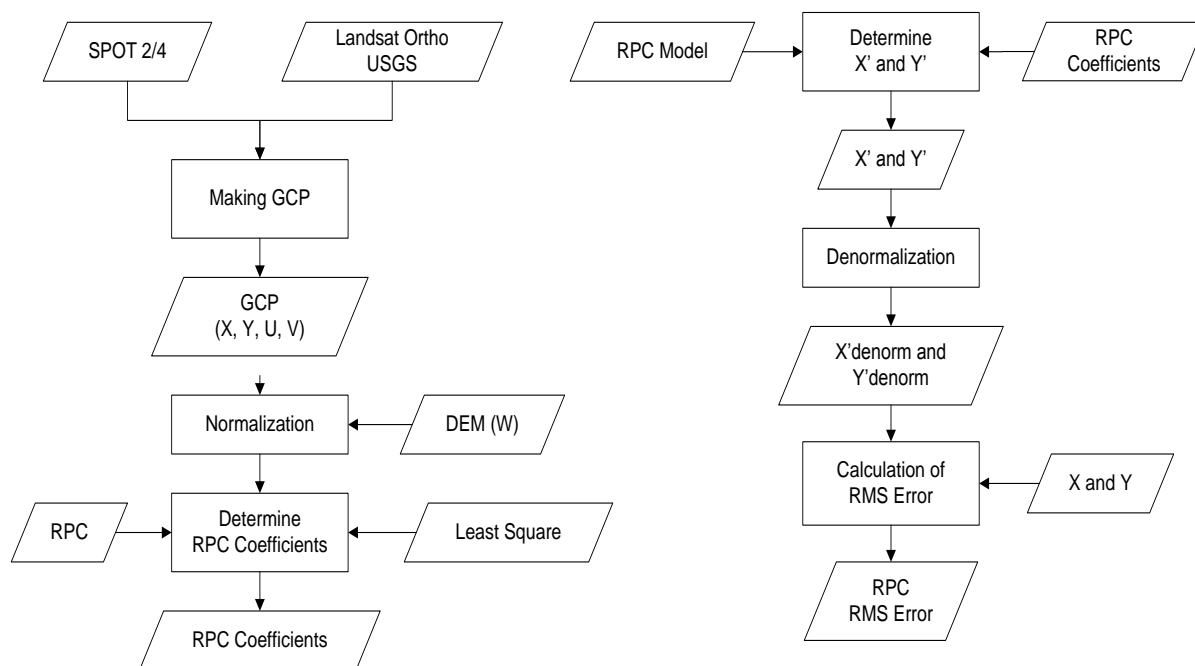


Figure 2. The flowchart of RPC process

Grodecki *et al.* (2004). This study used the techniques because they were more simpler and easier to implement.

In this study, normalization technique used the Equation 2 (Candra, 2011) as follows:

$$X_{norm} = \frac{2(X - X_{min})}{(X_{max} - X_{min})} - 1 \quad (2)$$

where,

X_{norm} = Normalization of X in image coordinates

X = X in image coordinates

X_{max} = Maximum value of image coordinates

X_{min} = Minimum value of image coordinates

and the denormalization technique was calculated by using the Equation 3 (Candra, 2011) as follows:

$$X_{denorm} = (0.5(X' + 1)(X_{max} - X_{min})) - X_{min} \quad (3)$$

where,

X_{denorm} = Denormalization of image coordinates

X' = Determined by RPC model

X_{max} = Maximum value of image

X_{min} = Minimum value of image coordinates.

The GCPs are obtained GCPs is by matching points on the SPOT-4 as subject image to points on the Landsat Ortho USGS data as reference image. The normalization is technique to change the GCPs values from real values to be -1 until 1. The aim of this

technique is to make it easier to determine the coefficients of RPC. It can also produce better numerical accuracy. Least square method is used to determine RPC coefficients. They are used to build RPC model.

After RPC model were built, X' and Y' can be obtained from the model. The denormalization is technique to turn back the GCPs values from -1 until 1 to be real values. Then RMS error is obtained from calculation X' denorm and Y' denorm with X and Y (Figure 2).

3 RESULT AND DISCUSSION

Theoretically, the spread of GCP will contribute to the resulting of orthoimage accuracy. So the resulting of RMS Error represents the position accuracy on the entire surface of the image of SPOT-4. This study obtained 15 GCPs by matching points on the SPOT-4 as subject image to points on the Landsat Ortho USGS data as reference image. The points were spread evenly on the scene SPOT-4 data as shown in Figure 3.

The order-1 of RPC model was used to determine RPC coefficients. The program in Visual C++ was built in this study to calculate RPC coefficients (Table 1).

The results show that the RMS Error is less than 1 pixel (Table 2). It varies between 0.07 to 0.85 pixels. The smallest RMS Error value at GCP12 (0.07 pixels) and the highest one is at GCP13 (0.85 pixels). The average of RMS Error is 0.49 pixels.

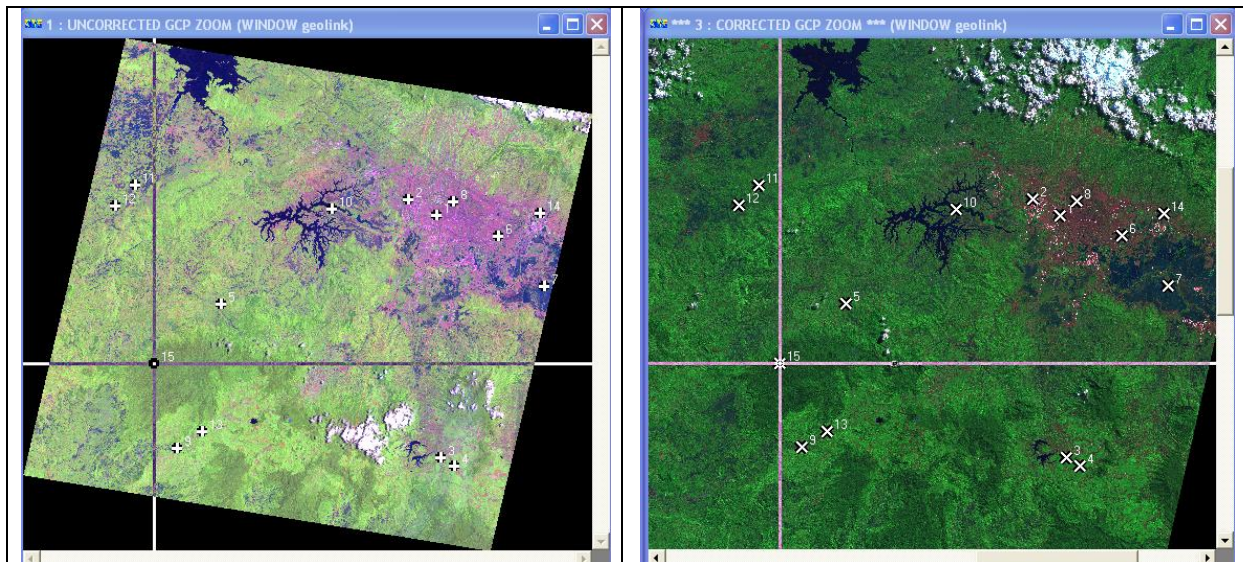


Figure 3. The GCP distribution on satellite image. The SPOT-4 as subject image (left) and Landsat Ortho USGS data as reference image (right)

Table 1. THE RPC COEFFICIENTS

No.	Coefficients	Line (X)		Sample (Y)	
		c_i	d_i	e_i	f_i
1	Constants	0.000155	1.00000	-0.00004	1.00000
2	U	-1.00098	0.00054	0.00039	-0.00002
3	V	-0.00116	-0.00028	0.00011	-0.00012
4	W	0.000008	-0.00054	0.000008	-0.00006

U = Easting coordinates of GCP
 V = Northing coordinates of GCP
 W = Height of GCP

Table 2. RMSE OF ORTHORECTIFICATION USING RPC

Point Code	GCP (m)			Image Coordinate		RMSE (pixel)		
	U	V	W	Row (X)	Column (Y)	Row	Column	Row-Column
GCP01	799146	9225086	662	3499	1668	-0.34	0.40	0.53
GCP02	780831	9236814	725	2586	1082	0.01	-0.17	0.17
GCP03	784561	9234643	720	2772	1190	0.00	-0.48	0.48
GCP04	785211	9202139	1540	2803	2816	-0.65	0.21	0.68
GCP05	792961	9231879	676	3191	1328	0.02	-0.22	0.22
GCP06	786847	9236527	745	2886	1096	-0.12	-0.25	0.28
GCP07	770535	9235475	656	2072	1149	-0.33	-0.49	0.59
GCP08	744112	9238738	319	754	987	-0.50	-0.37	0.62
GCP09	741464	9235939	356	622	1127	-0.37	-0.37	0.53
GCP10	798520	9234928	694	3468	1176	-0.43	0.41	0.60
GCP11	746705	9214808	1476	883	2184	-0.24	0.46	0.52
GCP12	749777	9203402	941	1036	2754	-0.07	-0.01	0.07
GCP13	753090	9205642	1094	1201	2641	-0.38	-0.76	0.85
GCP14	786977	9200981	1530	2892	2873	0.28	-0.68	0.74
GCP15	755610	9222733	1034	1328	1787	0.44	-0.09	0.45

4 CONCLUSION

RMSE of GCPs obtained from the study was less than 1 pixel. It varied between 0.07 to 0.85 pixels. The smallest RMS Error value at GCP12 was 0.07 pixels and the highest one at GCP13 was 0.85 pixels. The average of RMSE was 0.49 pixels.

The technique of normalization and denormalization worked well because the RMSE result was less than 1 pixel. Thus, it can be used for orthorectification implementation. RPC did not depend on physical and satellite orbit parameters. The RPC was simpler and easier to apply than RSM. Thus, RPC can be used as an alternative of orthorectification method to the RSM.

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